chandeliers (wooden frames) were carried by the American troops with which to erect their fortifications. Altho the ground was frozen, yet by reason of a southwest wind the night was "remarkably mild," and the light of the full moon aided the men in their work. A light haze, or perhaps a radiation fog with the moist southwest wind, combined with the smoke from the cannonading which the Americans had commenced earlier in the evening, settled down over the town and the lowlands and concealed the progress of the work on the heights.

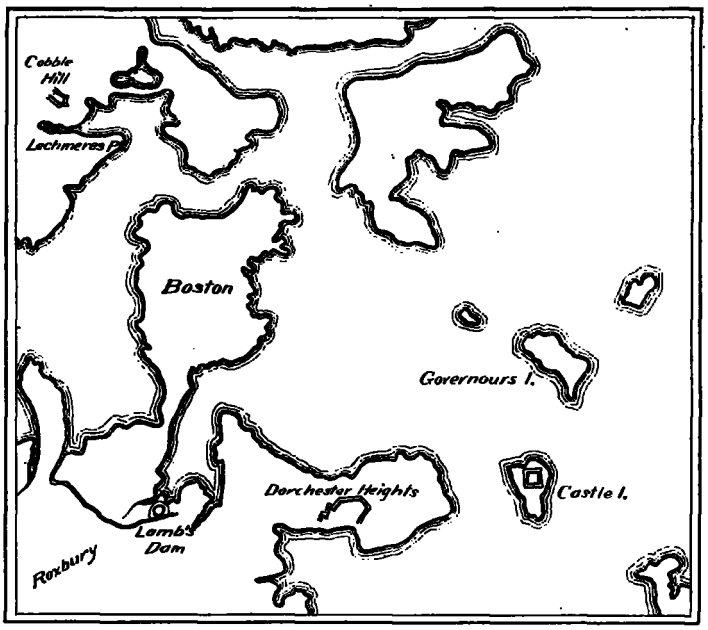

FIG. 2.—Sketch map of Boston with its environs in 1775 and 1776. (From Frothingham's History of the Siege of Boston.)

The cannonading of the night, the southwest wind carrying any sound of the American operations out toward the bay, and the smoke and fog kept the British from any suspicion of what Washington's men were doing, so that when morning broke Howe's men were much surprised to find what the Americans had accomplished during the night. Looking thru the early morning fog, the fortifications "seemed of indefinite magnitude," and both General Howe and Admiral Shuldham realized that their positions were insecure as long as the Americans remained on Dorchester Heights. Consequently General Howe decided to prepare to attack, and about noon between two and three thousand men, under command of General Jones, began to embark in transports. The plan was for them to drop down in the late afternoon or early evening to Castle Island, whence they could cross to the cove southeast of the American position and attack the Americans from the rear early Wednesday morning.

Tuesday morning had dawned clear and mild, with a bright sun and a warm southerly wind. During the afternoon, however, the storm which had been indicated by preceding fog and winds, and which had probably been advancing up the Ohio Valley, must have reached New York State. A marked low-pressure area there would have produced strong southeast winds in the vicinity of Boston. In the afternoon the wind blew furiously, so billowing the harbor that three of the transports were blown upon Governors Island before reaching the Castle. By night a "rank storm," as one of the British officers called it, had set in with a fury "such as few remember to have heard," and the rain fell in torrents, so drenching the Americans who had all day continued to strengthen their position, that one of them wrote in his journal "I never before felt such cold and distress as I did this night, and I believe it was the case in general with our men."

As morning drew near there was no abatement of the storm, and Wednesday, March 6, commenced amid torrents of rain and a boisterous wind from the southeast. The center of the storm had probably past into northern Vermont or New Hampshire, and with the furious southeast gale that was blowing, such a surf beat upon the Dorchester shore where the troops must have landed, that "an attempt to land must have proved fatal."

Altho the rain and the wind continued the greater part of Wednesday with little less fury the time was not being lost by the men under General Thomas. When the storm and the surf had sufficiently subsided for the British to attack, they realized that the American position was too strong for them, and by night (Wednesday, March 6) the evacuation of Boston had been decided upon. Eleven days later the city was abandoned, and the entire force under General Howe dropt down in their transports toward Nantasket, sailing thence for Halifax ten days later.

Of the British plan and the results of the storm General Washington wrote Major-General Lee on March 14, as follows:[2] "A very heavy storm of wind and rain frustrated their design; in my opinion the most fortunate circumstance for them and unfortunate for us that could have happened, as we had every thing so well prepared for their reception that I am confident we should have given a very good account of them." Whether Washington was right, and whether the British must have evacuated the city had they attacked, will never be known; but it seems certain that the closing chapter of the siege of Boston would have been different had the weather not frustrated General Howe's plans.

THE WORK OF PROF. CARL STÖRMER ON BIRKELAND'S THEORY OF THE AURORA BOREALIS.

By JOHN A. ANDERSON, Ph. D. Dated Johns Hopkins University, Baltimore, Md., May 29, 1908.

The general appearance of the streamers, bands, etc., of the aurora borealis is so similar to some of the phenomena accompanying the passage of cathode rays thru rarified gases that most of the modern theories which aim to account for it assume that the aurora is produced by cathode rays passing thru the upper atmosphere. The altitude at which the aurora appears (about 40 miles), where the atmospheric pressure is about what is commonly found in our vacuum tubes, tends to support this view as to the cause of the luminous phenomena observed. Another fact also pointing to the same conclusion is that the streamers increase in intensity downward, which is what we should expect since cathode rays are more strongly absorbed the greater the pressure of the gas thru which they pass, and hence with increase of pressure the luminosity of the air caused by them should increase up to very near the point where they are completely absorbed.

The theories of the aurora accordingly differ chiefly in the way in which they account for the origin of the cathode rays. The fact that great auroras very frequently are seen at a time when some sun spot is showing unusual activity has led to the general belief that the first cause of the aurora is to be sought in the sun.

There are three theories which seem to be able to account in a more or less satisfactory manner for the chief characteristics of the aurora. These are (1) the theory of Arrhenius (Ofversigt, 1900); (2) the theory of Nordmann; (3) the theory of Birkeland (Archives, 1896).

(1) Arrhenius's theory assumes that the sun sends out negatively charged particles (larger than atoms) which, repelled by light pressure, reach our atmosphere, where they are discharged by ultra-violet light from the sun, thus giving rise to cathode rays, which move in spirals around the magnetic

[2] Jared Sparks: The Writings of George Washington. Vol. III. (Hilliard, Gray & Co. Boston. 1834.)

lines of force until they have penetrated sufficiently deep into the atmosphere to be absorbed, when they give rise to the luminosity observed.

(2) The theory of Charles Nordmann assumes that electrical disturbances accompanying sun spots and prominences on the sun give rise to Hertzian waves, which, on being absorbed in the rarified upper layers of our atmosphere, give rise to cathode rays, which then move along the lines of force and produce the aurora as in the theory of Arrhenius.

(3) Birkeland assumes that the cathode rays emanate from the sun directly, and most copiously from the sun spots. On approaching the earth they are directed into certain definite channels by the terrestrial magnetic field, and on striking the atmosphere they set up electrical currents there, which in turn send out cathode rays. These "secondary" cathode rays are then responsible for the aurora as in the other theories. Auroras might also be caused directly by the cathode rays from the sun.

Birkeland supported his theory by some experiments with a vacuum tube; in the path of the cathode rays from this tube he placed a small spherical electromagnet whose surface was covered with a layer of platinobarium cyanide. The small magnet could be rotated about an axis which made a small angle with its magnetic axis, and was so wound that its magnetic field represented that of the earth as closely as possible.

On magnetizing the sphere he found that the luminosity, instead of being uniform over the side facing the cathode, was limited to certain regions only. There was usually a ring of luminosity nearly coincident with the equator; also a ring surrounding each magnetic pole, which with a certain relation between the cathode fall of potential and the magnetic field due to the sphere, had a radius of about 20°. Besides these, certain other rings appeared having their centers between the equator and the poles.

Birkeland believed that the cathode rays produced currents in the gas surrounding the sphere, and that the luminosity observed on the surface of the sphere was due to cathode rays sent out from these currents.

Applying these results to the case of the earth and the sun he concluded that cathode rays sent out from the sun, on coming within the influence of the earth's magnetic field, are directed into paths similar to those observed in his experiments. Electric currents in our upper atmosphere are thus produced which disturb the earth's magnetic field, and also give rise to cathode rays producing the auroral displays.

In a paper entitled "Sur les trajectoires des corpuscules electrisés dans l'espace sous l'action du magnétisme terrestre avec application aux aurores boréales,"[1] Prof. Dr. Carl Störmer, of Christiania, derives mathematical expressions by means of which the path of a cathode particle sent out from the sun in the direction of the earth may be calculated. This is an extension of the problem solved by H. Poincaré of finding the path of a cathode particle acted on by a single magnetic pole, inasmuch as it supposes the particle acted on by a magnetic doublet.

In order to simplify the treatment as much as possible, he supposes the earth's magnetic field replaced by one due to a doublet of moment 8.52×10^{25}, supposed to be placed at the earth's center.

He finds that the dimensions of the paths are determined by the value of $\sqrt{\frac{M}{H_0 \rho_0}}$, where

M = magnetic moment of the doublet, and

H_0 = strength of the magnetic field in which a charged particle of given mass and velocity would move in a path whose radius of curvature is ρ_0.

For the earth M is fixt. Hence the size of the paths depends upon the value of the product $H_0 \rho_0$, that is, upon the nature of the cathode rays.

The observations of Birkeland are accounted for in a satisfactory manner since he finds that the paths observed by him are all found among those calculated, by assuming different values for certain consonants in the equation.

The appearance of the aurora on the night side of the earth is shown to follow at once provided $H_0 \rho_0$ has such values as correspond to cathode rays or to β-rays from radium. It seems impossible, however, that the heavier charged particles required by Arrhenius's theory could be deviated sufficiently to strike the atmosphere in any place except on the day side. Rays sent out from the sun, in order to strike the earth must be sent out in a definite direction with respect to the earth's magnetic axis. If the center of emission is some sun spot or facula which sends out a rather narrow conical beam, this could strike the earth for only a short time owing to its diurnal rotation, which would soon change the position of the earth's magnetic axis relative to the axis of the cone of cathode rays. On the following day, when the earth's magnetic axis would again occupy the same position relative to the sun, the sun itself would have turned thru an angle of about 15°, and accordingly if the beam is narrower than this no cathode rays would strike the earth. If, on the other hand, the source on the sun sends out rays in all directions inside a cone of considerable angle, it follows that the disturbance on the earth might be repeated on several successive days, and at about the same hour each day. This has frequently been observed to be the case with auroras. Störmer also shows that a source of limited area may produce auroral streamers, or an auroral band, according to the nature of the rays and the direction in which they are emitted. His calculations for the actual dimensions of the bands agree quite well with those observed.

The diameter of the zone of maximum frequency is also calculated for the various values of the product $H_0 \rho_0$; but the value comes out too small, being only from 2° to 5° for cathode rays and β rays of radium, while the actual diameter is something like 20°. Störmer thinks this discrepancy is due to his assumption that the earth's magnetic field may be regarded as due to a doublet at the center of the earth, and that it will disappear when calculations are made using the actual magnetic field of the earth.

The calculations are all very laborious, as the paths must be found by quadratures, the author not having succeeded in integrating his equations up to the time of writing the paper. The results of the more exact calculations will be awaited with interest, as the theory seems very promising.

If these more exact calculations give results which are in substantial agreement with observations, as Doctor Störmer seems to expect, Birkeland's theory will have to be considered as perhaps the most important of the theories of the aurora that have been proposed up to the present time.

An interesting question which arises in connection with this theory, and one which has furnished the strongest objection to it, is the origin of the cathode particles and their escape from the sun.

There are a number of ways in which it is known that cathode particles or negative electrons may be set free, the chief of which are—

1. Ionization of a rarified gas by strong electric fields, such as exist near the cathode in an ordinary vacuum tube.
2. Radio-active bodies, such as radium, thorium, actinium, and their products, some of which are continually emitting these particles at very high velocities.
3. Action of ultra-violet light on substances, especially the metals. Some substances become active even when acted on by light in the visible spectrum.
4. Incandescent solids, or very hot bodies in general.
5. Secondary cathode rays are usually emitted by substances

[1] Archives des Sciences Phys. et Nat., July-Oct., 1907.

upon which so-called primary cathode or β rays fall. The primary rays may be produced by any of the methods given above. The secondary rays may, by impinging on substances, give rise to tertiary rays, and so on.

To these may be added another way, which has been described by Professor Birkeland, namely, that cathode rays are sent out from a rarified gas when it is traversed by an electric current. This was demonstrated by means of a vacuum tube consisting of a large spherical bulb with two tubes of small bore sealed into it at right angles to each other and situated 90° apart on a great circle of the sphere. The electrodes were sealed into these tubes, and hence when a discharge was past the current entered the large bulb from the small opening in one of these tubes and had to leave it thru the similar opening of the other, the object being to get a current that should be confined to only a limited portion of the gas in the bulb. One of the tubes projected some distance into the bulb, and the path of the current when no magnet was brought near the bulb was approximately a straight line between the openings in the two tubes. With a suitably high vacuum a faint glow was seen thruout the whole volume of the bulb, besides the comparatively brilliant path of the current, and the walls of the bulb phosphoresced with a faint yellow light, indicating that they were being bombarded with cathode particles.

On bringing one pole of a very powerful electromagnet near the bulb, the path of the current was bent into a curve, and the glow which before filled the bulb was drawn up into a band whose surface contained the curved current and also the lines of magnetic force. These phenomena indicate that the cathode particles were sent out from the gas in the path of the current, and in a magnetic field their paths would, of course, be spirals around the lines of force.

The most natural assumption to make regarding the origin of the cathode rays sent out from the sun is that they are emitted by the photosphere itself since this is undoubtedly at a very high temperature. The objection to this is that such cathode rays could perhaps never penetrate the deep solar atmosphere which they would have to do in order to reach the earth. We do not know how dense the solar atmosphere is, but most estimates agree that near the photosphere it is very much denser than that of the earth, and since the β rays of radium, which are far more penetrating than ordinary cathode rays, are completely absorbed by a layer of gas of much smaller extent than our atmosphere, it follows that the solar atmosphere would effectually stop any negative electrons emitted by the photosphere.

Evidently, then, the source of the cathode rays demanded by Birkeland's theory must be lookt for high up in the solar atmosphere, where the density is extremely small. There are several ways in which cathode rays might originate even in the upper regions of the solar atmosphere where the density is sufficiently small to favor the ready escape of the particles into space. It seems, however, necessary to connect this emission of electrons in some direct way with the sun spots, or, more definitely, with the moments of great activity in a sun spot, and this limits the number of ways, by excluding the third one mentioned above. The first one is excluded because an extended rarified gas is too good a conductor to allow any strong electric fields to exist in it. The fifth may also be excluded for obvious reason.

There remain, then, the emission of cathode rays from the gas thru which a current flows, and the emission of β rays from radio-active substances. Such violent disturbances as are manifest in sun spots at times may well produce electric currents in the upper regions of the solar atmosphere, and if such currents really send out cathode rays of any considerable penetrating power, these might escape into space and so reach the earth.

Violently eruptive sun spots might also project into the upper regions of the sun's atmosphere certain radio-active material if it exists in the sun, which might emit β rays copiously enough to produce on the earth the phenomena of the aurora in accordance with Birkeland's theory.

THE WARM STRATUM IN THE ATMOSPHERE.[1]

By Prof. A. LAWRENCE ROTCH. Dated Blue Hill Meteorological Observatory, Hyde Park, Mass., April 24, 1908.

While not presuming to offer an explanation of the isothermal or relatively warm stratum in the high atmosphere which the recent letters in Nature have made known to others than meteorologists, I desire to point out that it is probably a universal phenomenon, existing at some height all around the globe. This inversion of temperature was first discovered by M. Teisserenc de Bort with the sounding balloons sent up from his observatory at Trappes, near Paris, France, in 1901, and almost simultaneously by Professor Assmann from similar German observations. Since then almost all the balloons which have risen more than 40,000 feet above central Europe (that is, near latitude 50°) have penetrated this stratum, without, however, determining its upper limit. Teisserenc de Bort early showed that its height above the earth, to the extent of 8,000 feet, varied directly with the barometric pressure at the ground. Mr. Dines[2] gives the average height of the isothermal layer above England as 35,000 feet, with extremes of nearly 50 per cent of the mean. Observations conducted last March by our indefatigable French colleague, Teisserenc de Bort, in Sweden, just within the Arctic Circle, showed that the minimum temperature occurred at nearly the same height as at Trappes, namely, 36,000 feet, altho Professor Hergesell, who made use of sounding balloons over the Arctic Ocean near latitude 75° N., during the summer of 1906, concluded that the isothermal stratum there sank as low as 23,000 feet.

During the past three years the writer has dispatched 77 sounding balloons from St. Louis, Mo, U. S. A., latitude 38° N., and most of those which rose higher than 43,000 feet entered the inverted stratum of temperature. This was found to be somewhat lower in summer, but the following marked inversions were noted last autumn: October 8, the minimum temperature of —90° F. occurred at 47,600 feet, whereas at the maximum altitude of 54,100 feet the temperature had risen to —72°; October 10, the lowest temperature of —80° was found at 39,700 feet, while —69° was recorded at 42,200 feet, showing a descent of nearly 8,000 feet in the temperature inversion within two days. The expedition sent out jointly by M. Teisserenc de Bort and the writer, on the former's steam yacht *Otaria*, to sound the atmosphere over the tropical Atlantic during the summer of 1906, launched sounding balloons both north and south of the equator within the Tropics, and altho some of these balloons rose to nearly 50,000 feet, they gave no indication of an isothermal stratum. In fact, the paradoxical fact was established that in summer it is colder 8 miles above the thermal equator than it is in winter at the same height in north temperate regions. This results from the more rapid decrease of temperature in the Tropics and the absence of the numerous temporary inversions which, as Mr. Dines has pointed out, are common in our regions below 10,000 feet. If, therefore, as seems probable, the isothermal or relatively warm stratum does exist in the tropical and equatorial regions, it must lie at a height exceeding 50,000 feet, from which height, as the data quoted show, it gradually descends toward the pole, at least in the Northern Hemisphere.

TORNADOES IN LOUISIANA, APRIL 24, 1908.

By I. M. CLINE, District Forecaster. Dated New Orleans, La., June 12, 1908.

An area of low pressure which was central over Utah on the morning of April 22 moved eastward and increased in inten-

[1] Reprinted from Nature, May 7, 1908.
[2] Nature, February 27, 1908, p. 390.